Status and Open Issues for GYRO - DIII-D Validation

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• Review current results

• Issue #1: Particle fluxes

• Issue #2: Underprediction of heat fluxes and fluctuation levels at large r/a

• Thoughts on what to do next + lessons learned

• Caveat: this analysis is all using set of L-mode discharges from A. White’s 2007 expt. Not clear yet how general these results are.
Profiles + Fluctuations

Shot 128913 1300-1700 ms

Normalized radius (r/a)

E_r (kV/m)

Normalized radius (r/a)

T_e, T_i (keV)

\bar{\tilde{n}}/n, \bar{\tilde{T}}/T

40 - 400 kHz \bar{\tilde{n}}/n

40 - 400 kHz \bar{\tilde{T}}/T

UCSD

GENERAL ATOMICS
Ex: Applying BES PSF to GYRO Simulation Data

• IDL post processing tool written to generate synthetic BES array; PSF form taken from calculation by M. Shafer

• Tool first interpolates PSF data (generated on a regularly spaced \((R,Z)\) grid) onto a grid compatible with GYRO data (which uses a field-line following \((r,\theta,\alpha)\) coordinate system)

• At each time point of interest, record
  
  - Synthetic signal defined as
    \[
    \delta n_{\text{synthetic}}(x,y,t) = \frac{\int d^2 x' \psi^{PSF}(x-x',y-y') \delta n_e^{GYRO}(x',y',t)}{\int d^2 x' \psi^{PSF}(x-x',y-y')} 
    \]

  - GYRO signal at gridpoint closest to nominal BES location (term this signal the unfiltered GYRO signal in this poster)
**Synthetic Diagnostic Array Layout**

- **Create a 5x6 synthetic BES array centered in middle of simulation**
  - Offset 4 cm below midplane as in experiment
  - 0.9 cm radial spacing, 1.2 cm vertical
    - probably slightly too big; working to resolve
  - Use same PSF for all channels

- **Create 5 synthetic CECE measurements across radius**
  - Offset 5.5 cm above midplane, also as in experiment
  - Use pairs asymmetric Gaussian for PSF/"spot" function
  - Radial 1/e² diameter = 1 cm, 3.8 cm vertically
  - Because sim is local, all radial locations should be equivalent, can average to improve syn. CECE statistics

- **Do calculations at 4 equidistant toroidal angles to get more statistics**

- **General note: believe synthetic BES diagnostic to be fairly mature and complete, but synthetic CECE results should be considered to be more preliminary**
  - Still need to consider several physics effects for CECE, such as relativistic electrons and temperature anisotropy
BES and CECE Fluctuation PSF Visualizations in (R,Z) Plane for r/a = 0.5

$\frac{\delta n_e}{n_{e0}}$  

$\frac{\delta T_e}{T_{e0}}$

50% contours of BES and CECE PSFs
Linear growth rates

Rho = 0.75

Rho = 0.5
Fluxes vs. time and $k_\theta \rho_s$

$\rho = 0.5$
Use $t > 200$

$\rho = 0.75$
Turn on $\gamma_{ExB}$
@ $t = 200$
Use $t > 300$
Fixed-Gradient Sims Match Heat Fluxes and RMS Fluc. Levels at $r/a = 0.5$, underpredict $r/a = 0.75$
Fixed-Gradient Sims Match Heat Fluxes and RMS Fluc. Levels at r/a = 0.5, underpredict r/a = 0.75

![Graphs showing Q_i (MW) and Q_e (MW) against normalized rho](image)

![Bar chart showing relative fluctuation level (%) vs normalized radius rho](image)
Fixed-Gradient Sims Match Heat Fluxes and RMS Fluc. Levels at r/a = 0.5, underpredict r/a = 0.75

\[ Q_i \text{ (MW)} \]

\[ Q_e \text{ (MW)} \]

\[ \frac{\tilde{n}}{n_{syn}} \]

\[ \frac{\tilde{T}}{T_{syn}} \]

\[ \frac{\tilde{n}}{n} \]

\[ \frac{\tilde{T}}{T} \]

GYRO with exp. profiles

Experiment

Normalized radius $\rho$
Correlation Function Comparisons

Rho = 0.5

Rho = 0.75
Obtain good agreement in “shapes” of spectra at both locations

- Observe good agreement b/w synthetic and exp. measured lab-frame frequency spectra
  - Unfiltered GYRO in black
  - Dashed red curves are synthetic results “renormed” to exp. level

- Key observation: seem to get “shape” of eddies right even if we don’t get magnitude

- But this is using low frequency resolution for simulations (~20 kHz vs. 5 kHz for expt)...
Increase frequency resolution brings out finite Dn structure of synthetic signals

- If we calculate synthetic spectra with double freq resolution, observe features well-correlated with discrete n values
  - Features robust with even higher resolution, but SNR decreases quickly

Dashed lines are prelim. 32 mode Δn=4 results
SNR vs. frequency resolution
**Issue 1: Particle fluxes**

- According to ONETWO, particle flows dominated by highly uncertain wall source—can’t say how well GYRO is predicting flows.

- **Implications**:
  - Probably better to keep density profile fixed in flux-matching TGYRO simulations here.
  - Impact on intrinsic rotation studies (where rotation pinch may be correlated particle pinch).
Issue 2: Underpredicting heat fluxes at r/a > 0.5

- **Key observations:**
  - Deficit is in $Q_i$ -> issue is not just missing ETG/paleo
  - “Shapes” of synthetic (i.e. long-wavelength) signals match well against experiment
  - Particle flux at r/a = 0.75 currently pinch-dominated from high(er)-k modes
  - **Suggests we need more power in long wavelengths**

- **Possibilities**
  - Dynamic impurities? $Z_{\text{eff}} \leq 1.3$
  - Lack of up-down asymmetry in simulations?
  - Missing long-wavelength transport
    - Simple est. suggests below (but maybe near) KBM threshold, RBM maybe? But should show up in GYRO, EM had little effect on NL results. Need additional local/non-local analysis?
  - Numerical issues due to high collisionality
    - $v_{ei} = 0.4 \ a/C_s$ at r/a = 0.75; hope to address with upcoming $\nu^*$ experiment
  - Profile uncertainty and stiffness
    - Use TGLF to take a pass, but initial GYRO runs found less stiffness than earlier rho-star simulations
    - Need work on translating b/w TGLF + GYRO I/O, ExB shear differences and uncertainty
    - Uncertainty in mag. equilibrium? Use of Miller model (rather than 2D EFIT)?
  - Core-edge coupling: turbulence from SOL/edge region “spreads” in
    - **CAN’T BE ADDRESSED BY GYRO- need edge GK eqn., open field lines, neutrals, etc.**
    - **But:** how far in do we realistically think it spreads (r/a = 0.8? 0.7? 0.6??)
    - Less drastically, need to go to non-local, flux-matching simulations?
Some thoughts on V&V realities (in no particular order)

- Not obvious L-mode transport is always as stiff as sometimes assumed
  - But: even large local gradient changes don’t lead to big changes in profiles
  - Q: how much variation is there across “typical” L- and H-modes

- Don’t count on having a reliable particle flux measurement (esp. in low-power L-mode) until wall recycling/source can be better constrained
  - May impact momentum physics validation as well

- Errors in magnetic equilibrium and translation to sim. input files common and at least as significant as \( n_e/Te/T_i/E_r \) profile uncertainties

- Efficient data storage not very compatible with syn. diagnostics
  - Syn. diagnostics often use multiple interpolations in implementation

- Simulating collisional edge”-ish” (\( \rho = 0.75 \)) plasmas very challenging
  - Story will be more than just multi-scale ETG+ITG I suspect
  - How big do we think spreading from SOL in is?

- Validation experiments will involve strong trade-offs between fluctuation SNR, equilibrium profile measurements, model applicability, and range of parameters one can independently scan